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Environmental Assessment of Electricity Production from Rice Husk: A Case Study in Thailand

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ABSTRACT

The energy demand of Thailand has been steadily increasing at about 4% per year. A large portion of the fossil fuels is imported thus causing concern for energy security. In addition, utilization of fossil fuels is associated with emissions of CO_2, SO_2 and NO_X leading to environmental impacts. To approach the reduction of these problems, alternative (renewable) energy sources are proposed. Rice husk is a potential source of energy for an agricultural country like Thailand with high rice production. Rice mills can use the rice husk generated by them as a fuel to produce energy. However, the environmental profile of the energy production must be assessed to ensure reduced environmental damage. This study has been carried out at the Roi Et Green Project which is a pilot project of capacity 9.8 MW using rice husk as the feedstock. The power plant uses 290 tons of rice husk and 1,400 tons of water in one day, and has a power requirement of 1 MW. Net power output is 8.8 MW, which will be sold to Electricity Generation Authority of Thailand (EGAT) for 21 years under the small power producer (SPP) scheme. The raw materials consumed and environmental emissions of energy production from rice husk are determined. The study shows that the emissions of SO_2 and NO_X are lesser in case of coal and oil-fired power generation, but higher than for natural gas. The emission of CO_2 from combustion of rice husk are considered zero since they do not contribute to global warming. CO and dust emissions are slightly higher than conventional power production pointing to need for improving the combustion efficiency of the rice husk power plant. Overall, the study indicates that rice husk is a viable feedstock for electricity production and performs better than fossil fuels (especially coal and oil) from the point of view of environmental emissions.

1. INTRODUCTION

Since the year 2001, Thailand energy demand has been increasing at about 4% per year. In 2001, nearly 81% of total was from fossil fuels, 2% from hydropower and biomass resources accounted for 16.2% [1]. Utilization of fossil fuels has caused serious environmental impacts such as global warming caused primarily by CO_2 and acidification by SO_X and NO_X [2, 3]. Emissions of SO_x are particularly important for Thailand since a big source of fossil fuel used for electricity generation is indigenous lignite, which has very high sulphur content [1]. Fossil fuel combustion can cause NO_X emissions since the combustion temperatures are higher than 1,000°C [4]. In addition to the environmental problems, impact of fossil fuels is an economic issue for Thailand. The erstwhile National Energy Policy Office (NEPO) of Thailand (now Energy Policy and Planning Office) planned to focus on identifying suitable renewable energy sources, for instance biomass [5]. Also, the Electricity Generation Authority of Thailand (EGAT) buys electricity from small power producers (SPP) to support and replace conventional fossil fuel uses [6]. Unlike fossil fuels, biomass can be used for reduce greenhouse effect because trees absorb CO_2 as they grow and this carbon is released when the biomass is combusted. Thus, the net amount of CO_2 added to the atmosphere during energy production through the use of biomass over the entire life cycle is nearly zero [7, 8]. Also its combustion temperature is lower than fossil fuel combustion, it is anticipated that there will be lower NO_x emissions. Since biomass contains little sulphur compared to coal, it is also expected that there will be lower SO_x emissions [9]. To confirm whether energy production from biomass has lower emissions than conventional fuel production, an environmental assessment is done in this study using the life cycle assessment methodology. All the data, resource use and emissions, in this study will be based on 1 MWh of electricity production.

2. STATUS OF BIOMASS ENERGY IN THAILAND

Currently, attention has been paid to biomass as a substitute for fossil fuels not only in Thailand but also others, due to environmental and social-cost benefits [10]. Biomass is a by-product from various activities for instance wood waste from logging, forestry, saw milling from wood processing, industrial waste, municipal solid waste (MSW) from human activities and agricultural residues [2, 5, 11, 12]. Thailand is an agricultural based country producing large amount of agricultural residues annually [5, 12]. In 1998, the country has abandoned 28 million tons of biomass residues from bagasse, rice husk, palm oil and wood waste, which has a high electricity potential. If these unexploited residues are utilized, the total potential of biomass fuel sources and also power production capacity of the nation would be doubled [2, 5]. In the year 2001, the potential of agricultural residues can be accounted for as follows; 20 million ton of rice husk, 2.2 ton of palm oil residues, 50 ton of bagasse and 5.8 ton of wood waste, while available residues are 0.15%, 0.26%, 0.057% as well as 0.31% of each potential waste. The utilization rates as energy source are, 0.0005%, 0.006%, 0.0003% and 3×10^{-7}% of each potential [5]. These data clearly indicate that the potential of agricultural residues is much higher than the rate of utilization. Energy conversion of biomass differs by sources, conversion options, end-use applications and infrastructure requirements [13]. Two main process technologies of biomass to energy are thermo-chemical and bio-chemical/ biological [13, 14]. Thermo-chemical processes are divided into four types. Combustion is energy conversion by using stove, boiler or incinerator. Gasification is used for converting biomass into a combustible gas mix by partial oxidation at high temperature (800 - 900°C) and this gas can be used for producing methanol. To produce energy by pyrolysis process, biomass can be converted to all states - solid, liquid and gas - by heating it in the absence of air with almost efficiency 80%. Others, such as carbonization and cogeneration etc. are appropriate with different kinds of biomass. Bio-chemical/ biological conversion comprises of fermentation of biomass to alcoholic fuel, anaerobic digestion by some types of microorganisms and mechanical extraction to get oil [13].

3. RICE HUSK

Rice is cultivated in every region of Thailand, the total annual rice production being estimated as 20 million tons [5]. To produce rice in milling process, rice husk will be removed when passing through the process. Rice husk is the outer cover of rice that accounts for about 20% by weight of the rice [15, 16]. In the past, rice husk was mostly dumped as waste that caused waste disposal problem for the mills [15]. Also, when rice husk is fermented by microorganisms, methane is emitted contributing to global warming problem [17]. Rice husk is a fine and light particle and can cause breathing problems [15]. Hence, the rice mill owner should find the proper way to deal with this waste. Cement industry can use rice husk to add silica in the product itself because rice husk content high silica [18], and some amount of the waste are used as fertilizer in fields [15]. These ways are not enough to significantly reduce rice husk disposal problem. Another way that has been proposed is using the husk for energy purpose [5, 15]. Rice husk can be used as solid fuel by combustion process [19]. Many countries including Thailand use rice husk to produce electricity [20]. Only 50-70% of the husk in Thailand is utilized [12]. The characteristics of rice husk from the pilot plant study site - Roi Et Green Project at Roi Et province, Thailand - are presented in Table 1 [21].

4. CASE STUDY OF RICE HUSK ENERGY USAGE: ROI ET GREEN POWER PLANT

4.1 Background of the power plant

Thailand is the sixth largest rice producing country in the world. The Northeastern region around Roi Et province is particularly important as one of Thailand's major rice growing belts. Since the disposal of rice husk is the responsibility of the rice mill owner, ideas about how to gain benefit from the waste were considered. Power production from the rice husk, which can be utilized by the rice mill itself for its operation and can also be sold to the grid, is one such idea. To conduct the environmental assessment of such a rice husk fuelled power plant, the Roi Et Green Project, a pilot plant project of capacity 9.8 MW using rice husk as the feedstock, was selected. The plant has been developed as a demonstration project by NEPO for showing the potential of reduction in import of non-renewable energy sources and also reduces environmental emissions [5]. The project has been established since July 2000 and is a partnership between EGCO Green Co. Ltd. (95%) and Sommai Rice mill (5%). The power plant is besides the rice mill, which is located at Roi Et province, 510 km Northeast of Bangkok as. The capacity of the power plant is 9.8 MW. The plant itself uses 1 MW and the excess electricity demand after production, 8.8 MW, is sold to EGAT under the SPP scheme. Expected lifetime of the plant is 35 - 40 years.

Table 1 Components analysis of rice husk sample [21]

Parameter	Unit	Result	Basis
C	%	38.23	dry
H	%	5.80	dry
O	%	40.50	dry
N	%	1.21	dry
S	%	0.041	dry
Total moisture	%	11.94	as received
Ash content	%	14.22	dry
Low Heating Value (LHV)	kJ/kg	13,158.7	as received
High Heating Value (HHV)	kJ/kg	15,217.2	dry
Volatile matter	%	59.87	dry
Fixed carbon	%	18.56	dry

4.2 Materials and resources

Material consumption of the project includes 1,233 kg/MWh of rice husk from Sommai Rice mill and 5,952.4 kg/MWh of water from Shi River. Energy required for the plant operation, including power production and waste treatment, is 24 MWh in one day. Rice husk has been stored into two places. The new lot of the husk is stored indoor and the old is transferred to outdoor open pile. The amount of rice husk available depends on season and rice production capacity of the rice mill. If sometimes there is not enough rice husk from the Sommai Rice mill to meet the requirement, the power plant will buy from others rice mills within the Roi Et province. Fresh river water is pumped every 10 days and stored in the plant's reservoir. Raw water treatment consists of coagulation with poly aluminum chloride (PACl), sludge removal, filtering tank and demineralization tank. Water after treatment has pH 7.2, turbidity as 0.5 NTU, total suspended solid (TSS) is 50-70 ppm of water and conductivity as 1-5 μS/cm [22].

4.3 Process description

First of all, the system boundary of the study is set as shown in Fig. 1 [22], for doing the environmental assessment using the Life Cycle approach. Raw material, electricity and resource consumption, electricity generated, waste and emissions generated have been considered within the boundary. This figure also shows list of all flows-water, flue gas, steam, electricity and ash. The process started at, water from Shi River is treated before using for steam production. Particulates and ions in water must be removed to protect erosion of boiler. This is accomplished by coagulation by PACl. Sludge is removed as solid waste and is sent to the landfill. Then water is passed through filter tank and demineralization tank to remove ions by ion-exchange resin. After that, water is heated in the economizer using the waste energy from the hot flue gas released after steam production in the boiler. The heated water is then sent to the boiler. Rice husk is the fuel source for boiler and is ignited by burning paper during startup. Steam is produced at 300°C and is further heated by super heater to produce higher energy steam at approximately 400°C. This superheated steam is then used for steam turbine for generating electricity. The exhaust steam is then condensed to water by the cooling tower.

4.4 Emissions and waste generation/ treatment

Wastewater was produced from water pretreatment before using in boiler part. After coagulation, wet sludge is separated and the water removed. Dry sludge is sent to the landfill. This sludge contains the particulate in raw water. Regeneration of resin in demineralization part requires 35% hydrochloric acid and 50% sodium hydroxide. The blow down water has high turbidity and conductivity, and a pH 9.6 - 10.5. Water blow down from cooling tower is also considered as wastewater. The water has pH in the range of 8-9 and also some hardness and turbidity. Wastewater treatment steps are pH balance, coagulation and ion removal. Water discharge after the treatment has a pH value of 7 – 7.5, 0.6 kg/MWh of total suspended solid, turbidity and conductivity lesser than before treatment. The ash production from the power plant is bottom ash 0.017 kg/MWh and fly ash 0.1 kg/MWh [21]. The solid residues are sent to the landfill.

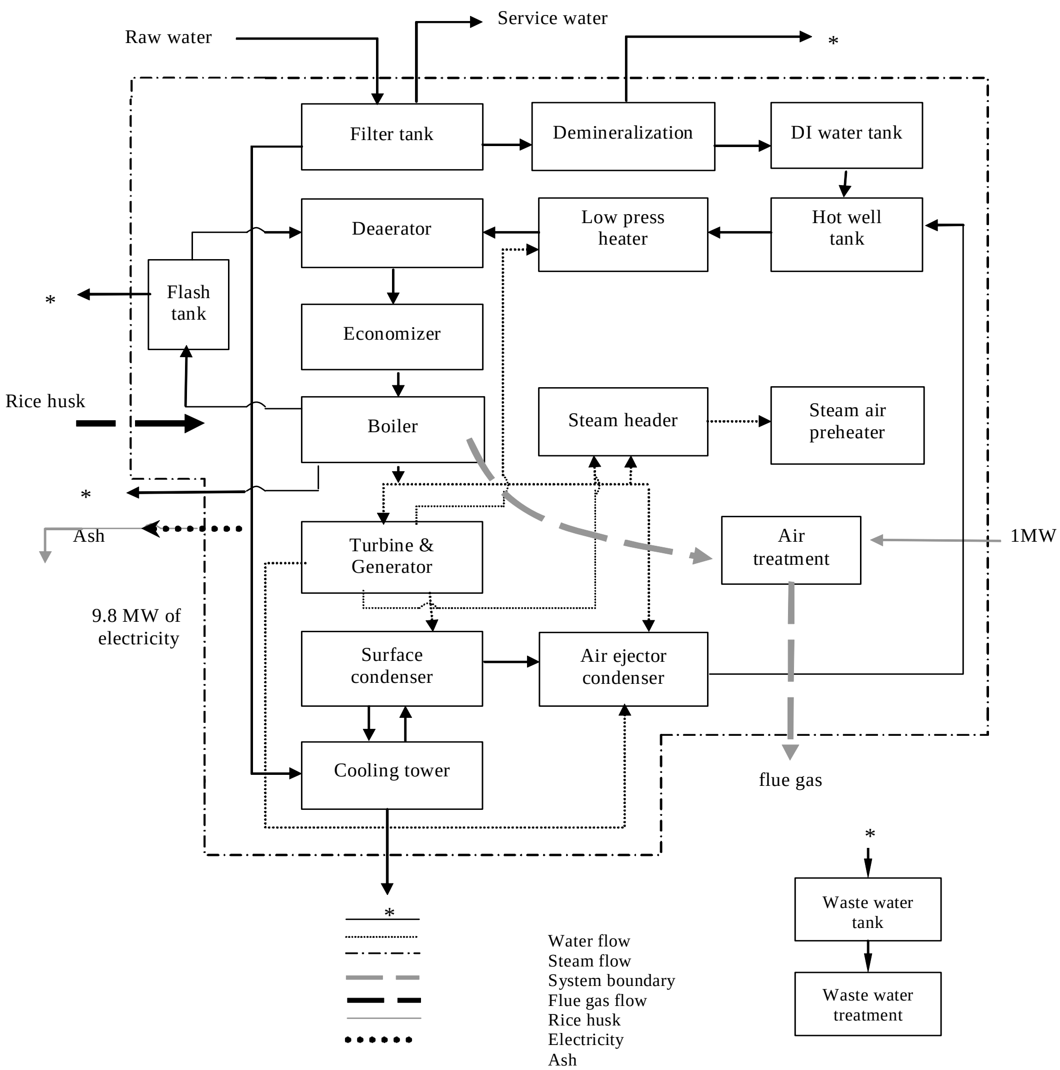

Fig. 1 System boundary of rice husk energy production

The flue gas generated is passed through a multi-cyclone and electrostatic precipitator for dust removal. Reference data for stack emission calculation, presented in Table 2, have been used to calculate intensities of SO_X, NO_X, CO and TSP (dust) emissions. At temperature 434 K, flue gas's flow rate was 68,510.8 m^3/h. However, for calculating the emissions loads, all values have been adjusted to STP. The results of the calculations are presented in Table 3.

Table 2 Reference data for stack emission calculation [21]

Parameter	Value	Unit
Stack Diameter	2.2	m
Air Velocity	7.3	m/s
Stack temperature	434	K
Flow rate	68,510.8	m^3/h
Moisture	11.8	%
O_2	7	%
CO_2	10.1	%
SO_2	15.9	ppm
N_2	79.6	%
NO_X (as NO_2)	175.1	ppm
CO	81.8	ppm
TSP (dust)	11.3	mg/Nm^3

The emission intensities of loads and intensities from conventional power plants are presented in Table 4. Emissions of CO_2, SO_2 and NO_2 are mostly come from coal-fired power plants. CO emission is highest from oil-fired power plants. Gas-fired power plants contribute least of all emissions. The last row of Table 4 has been computed for emission intensities of each parameter per MWh of electricity produced in Thailand.

Table 5 shows the comparison of these emissions intensities from rice husk power plant (Roi Et Green project) and conventional power plants to evaluate the environmental profile of rice husk energy as compared to conventional fuels.

Table 3 Emission data from Roi Et Green project [21]

Parameter	Value	Unit	Emission (kg/MWh)
SO_2	1.6×10	ppm	3.2×10^{-1}
NO_2	1.8×10^2	ppm	2.5
CO	8.2×10	ppm	7.1×10^{-1}
TSP (dust)	1.1×10	mg/Nm^3	8×10^{-2}

Table 4 Emission data from conventional power plants in Thailand, 2001 [22]

Types	Electricity production, MWh	CO_2		CO	
		Tons	Kg/MWh	Tons	Kg/MWh
Coal	17,338,580	22,011,748	1,269.52	3,421	0.197
Oil	12,947.2	10,521	812.61	3.52	0.27
Gas	56,247,083	31,997,720	568.88	11,070	0.197
Combined*	73,598,610	54,019,989	733.98	14,495	0.197

Types	SO_2		NO_2		TSP	
	Tons	Kg/MWh	Tons	Kg/MWh	Tons	Kg/MWh
Coal	48,005	2.77	101,212	5.84	633	0.037
Oil	16.6	1.28	37	2.86	12	0.927
Gas	19	0.0003	76,634	1.36	2042	0.036
Combined*	48,041	0.65	177,883	2.42	2686	0.036

* Weighted average of Coal, oil and gas-fired power plants

Table 5 Comparison of emission data of Roi Et Green project and conventional power plants [21,22]

Item	Emission (kg/MWh)				
	Roi Et Green	Coal	Oil	Gas	Combined*
CO_2	nearly zero	1.26×10^3	8.1×10^2	5.7×10^2	7.3×10^2
SO_2	0.32	2.8	1.3	3×10^{-4}	0.65
NO_X	2.5	5.8	2.9	1.4	2.4
CO	0.71	0.2	0.27	0.2	0.2
TSP (dust)	8×10^{-2}	3.7×10^{-3}	9.7×10^{-2}	3.6×10^{-3}	3.6×10^{-2}

* Weighted average of coal, oil and gas-fired power plants

5. RESULTS AND DISCUSSION

CO_2 from the Roi Et Green plant is from biomass combustion and hence, being part of the global carbon cycle, does not contribute to global warming. This is a distinct advantage of biomass-based energy production.

SO_2 emission of the project is less than emissions from coal and oil power plants. This is expected since the rice husk contains only about 0.4% sulphur. Even though SO_2 is higher than gas power plants, it is still lesser than the overall emissions from conventional electricity production. Similarly, NO_X emissions from the project are also lesser than coal and oil power plants, but higher than gas power plant. This is also as anticipated since combustion temperatures are lower than 900ºC which implies that all the NO_X will only be from the N-content in the fuel, not from the air. It must be noted here that the rice husk power plant performs better than conventional electricity production even though there are NO_X and SO_X removal equipment installed in the latter. Both these emissions contribute to acidification and in addition, NO_X also contributes to photochemical ozone formation and nutrient enrichment. Thus, the electricity production from rice husk is better than the conventional electricity production on these counts.

CO, formed when combustion is incomplete, is slightly higher for this study than conventional electricity production. This points to a need for improving the combustion conditions in the rice husk power plant. Total Suspended Particulates (TSP) from rice husk energy is quite large as compared to conventional electricity production. Dust emissions from rice husk power plant is higher than coal and gas power plants, but slightly less than oil power plants. It is known from previous research that rice husk combustion produces significant amounts of particulate matter. However, the rice husk power plant has multi-cyclone and electrostatic precipitator for dust removal. Hence the measurements will be checked again for confirmation of the results.

6. CONCLUSIONS

In Thailand, a large portion of the electricity production is from fossil fuels causing concern for energy security as well as environmental emissions of CO_2, SO_2 and NO_X. Biomass has been proposed as one of the alternative (renewable) energy sources of energy which can, to extent, offset the use of fossil fuels. This is especially suitable for Thailand since it is an agricultural country. However, it must be ascertained whether electricity production from biomass is really benign. This study considers the environmental assessment of power generation from rice husk, a waste product in rice mills. The study was carried out at the Roi Et Green Project which is a pilot project of capacity 9.8 MW using rice husk as the feedstock. The power plant uses 290 tons of rice husk and 1,400 tons of water in a day, and has a power requirement of 1 MW. Net power output is 8.8 MW, which is sold to Electricity Generation Authority of Thailand (EGAT) under the small power producer (SPP) scheme. The study shows that the emissions of SO_2 and NO_X are lesser in case of coal and oil-fired power generation, but higher than for natural gas. The emission of CO_2 from combustion of rice husk are considered zero since they do not contribute to global warming. CO are slightly higher than conventional power production, but in the same order of magnitude. This suggests a need for improving the combustion efficiency of the biomass power plant. TSP emissions from the biomass power plant are lower than oil-fired power plants, but higher than the other types. Overall, the study indicates that rice husk has a high potential for use as a feedstock for electricity production. It performs better than fossil fuels (especially coal and oil) from the point of view of environmental emissions.

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